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PROJECTION METHODOLOGY FOR LARGE-AREA RESIDENTIAL AND TRANSPORTATION EMISSIONS

1. INTRODUCTION

The concept of air cleanliness maintenance is becoming more and more important because of the environmental awareness of our society. The requirement for establishing plans for maintaining air quality (Air Quality Management, AQM) has been recognized by the general public in the meantime. One of the required fundamentals for a successful AQM is a survey of the emissions, with which the actual state and the production of certain contaminating materials is specified as to location, and their future development, that is, the development and time must be estimated. Therefore the AQM poses two tasks regarding the determination of emissions: the development of survey methods for the present state, which at the same time is suitable for extrapolation, as well as determination of suitable forecasting methods for the prediction of future emissions development. In this way we obtain the following structure of methods according to the size of the regions which are to be considered:

a) Superregional survey and forecasting (for example, for the area of the Federal Republic of Germany)
b) Regional surveys and forecasting (for example, on the state or governmental region level)
c) Local surveys and forecasting

Without a doubt in Case a) the requirements for detailed survey information and the accuracy of the forecasting methods are not always as high as in Case c), i.e., the effort and task definitions must be related optimally.

In the following contribution we will develop a methodology for survey and for forecasting emissions, which were used for the solving of the following tasks: For the Federal Republic of Germany the trend of certain contaminating substances from households and small users, as well as road traffic, had to be demonstrated for the years 1960 to 1980 for 5-year-intervals.[1)] The region of the Federal Republic of Germany was divided into 70 rectangular surface elements (each about 55 km . 70 km), and the emissions were determined for them. With this resolution, the methodology can be applied for the Case a) mentioned above (super-regional), and under certain conditions it can also be used for Case b), which will be discussed later on.

For the purpose of the present contribution within the framework of the "assessment of methodology", in the first main part (Section 2) we outline the methodology which was developed for large area survey and forecasting of emissions. During this description it is shown at what points the forecasting of future emissions must be started. In the second main part (Section 3) we describe the methodology which was used to predict the trend of the emissions up to 1980. The problems which occur are then discussed.

2. METHODOLOGY FOR LARGE AREA SURVEYS

2.1. General remarks

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1) "Spatial determination of the emissions from air-contaminating materials from industry, households and traffic in the Federal Republic of Germany", survey at the request of the Federal Ministry of the Interior, Bonn, 1976.

The basic equation which is the foundation of any emission determination is the following for a certain contaminating agent for a prescribed surface area:

$$\text{Total emission } S = \text{Consumption } V \cdot \text{Emission factor } e, \qquad (1)$$

if we consider a large area survey for the consumptions of households and small users as well as street traffic. In the case where the industry is discussed which was excluded here, instead of the consumption we would substitute an expression for the production of a certain process.

If we start with the basic equation which is modified for individual contaminating agents (Section 2.2), then the purpose of the methodology is to determine the corresponding consumption rates and emission factors for certain surface areas or regions (Section 2.4 and 2.5). In the present case, the Federal Republic of Germany is divided into 70 surface elements (average area about 55 km · 70 km) (Figure 1), according to the course of the integer number longitude curves and the course of the latitude curves with integer and half values. The position of each surface is characterized by specifying the value on the right (longitude degrees) and the maximum value (latitude degrees) of its southwest corner. The data about the consumption, of course, is not available for the surface elements, but only for Federal states and/or governmental districts, i.e., the consumption value for the surface elements must be determined using structural data (inhabitants, surface area) (Section 2.3).

The use of the basic equation given above for determining the total emissions allows one to design a calculation model which has the same sequence (Section 2.6) for the two regions under considerations, i.e., household and small scale consumption as well as street traffic, except for slight modifications (Section 2.6). After this it is demonstrated how the solution obtained with the developed methodology can be improved (Section 2.7).

2.2. Emission calculation

2.2.1. Household and small-scale consumption

The calculation of the total emission of a certain contaminating agent x from fuels for a given surface element K and a certain year is based on the following parameters which must be available as input data:

-Fuel consumption BV_K (Section 2.4.1) divided up according to

-- solid fuels (KOV)
-- liquid fuels (OEV)
-- gaseous fuels (GAV)

-Distribution factor f for each type of fuel consumption (Section 3.2.1) which considers the distribution as the consumption to individual heating units (f_E) and to collection heating units (f_S).

-Specific emission factors e_x (Section 2.5.1),
which depend on
-- heating installations - or fuel type (coal, oil, gas)
-- heating type: Individual heating e_{Ex}
Collective heating units e_{Sx}

In this way the basic equation for calculating the total emission S_{Bx} of a certain contaminating agent x (1) is the following for a given surface element

$$\begin{aligned} S_{Bx} &= \sum BV_K \cdot f \cdot e_x \\ &= (KOV \cdot f_E \cdot e_{Ex} + KOV \cdot f_S \cdot e_{Sx}) \\ &\quad + (OEV \cdot f_E \cdot e_{Ex} + OEV \cdot f_S \cdot e_{Sx}) \\ &\quad + (GAV \cdot f_E \cdot e_{Ex} + GAV \cdot f_S \cdot e_{Sx}). \end{aligned} \qquad (2)$$

Since the surfaces of the individual surface rectangles have different sizes (Figure 1), the total amount of emissions is referred to each surface area:

$$s_{Bx} = \frac{S_{Bx}}{F_K} .$$

The specific emission amounts are therefore comparable for all surface elements.

Basically regarding the parameters which appear in Equation (2), one should say that they are selected so that they describe the average yearly emission of a large area surface, approximately 55 km · 70 km, so that at least a qualitative trend analysis becomes possible over a large time interval. Here we consider the fact that the required survey work must stand in a reasonable relationship to the result. This is also true for the following arguments regarding the determination of the emissions in the area of road traffic.

2.2.2. Road traffic

The following parameters form the basis of the calculation of the total emission of a certain contaminating agent x from fuels for a given surface element K in a certain year, which must be available as input data:

- Fuel consumption KV_K (Section 2.4.2), divided up according to
  - -- Gasoline for city and rural traffic (VKV_S; VKV_L)
  - -- Diesel fuel for cities and rural traffic :(DKV_S; DKV_L)
- Specific emission factors e_x (Section 2.5.2), which depend on
  - -- Vehicle or fuel type (Car - gasoline, Truck - Diesel)
  - -- Driving style (average velocities for city and rural traffic)

In this way we obtain the following emission factors for a certain contaminating agent for the corresponding combinations:

Car/City - e_{VSx}

Car/Country - e_{VLx}

Truck/City - e_{DSx}

Truck/Country - e_{DLx}

Accordingly the basic equation for calculating the total emission S_{Kx} (1) of a certain contaminating agent x is the following for a given surface element:

$$\begin{aligned} S_{Kx} &= \Sigma\,(KV_{SK} \cdot e_{Sx} + KV_{LK} \cdot e_{Lx}) \\ &= (VKV_S \cdot e_{VSx} + VKV_L \cdot e_{VLx}) \\ &+ (DKV_S \cdot e_{DSx} + DKV_L \cdot e_{DLx}) \end{aligned} \qquad (4)$$

This total emission is again referred to the surface area, so that the emission amount of wall surfaces can be compared (Section 2.2.1):

$$s_{Kx} = \frac{S_{Kx}}{F_K}$$

2.3. Structural data

One of the problems when building a calculation model was the fact that the consumption data are given for current sources for the states of West Germany, and sometimes for their governmental districts. In the present case the knowledge of consumption data is required for the prescribed rectangles (Figure 1). Therefore, a method had to be found to determine the consumption values for the rectangles from the data given or to classify it according to the governmental districts (Section 3.2.2). In the following we will briefly describe how this data was obtained, but we will not give a formal description of how this is contained in the calculation model.

One important feature of the mothod used here is that the surfaces of the governmental distrists or rectangles are used as the correspondence variables, and that the corresponding population numbers are used as distribution variables. Both data types will be called "structural data" in the following. We would like to emphasize that the structural data do not enter directly into the emission calculation, i.e., they are not immediately included in the forecasting, which we will discuss later (Section 3). This means that the surface areas of the governmental districts, as well as the population numbers, are held constant as structural data (the Federal statistics of 1970 is used as a basis for the population numbers).

In detail one proceeds as follows. The structure of a rectangle is made up of several governmental district fractions just like a mosaic (Figure 2). Here again a certain governmental district fraction must be divided up into city parts and state parts where states with more than 20,000 inhabitants must be considered. This separation was required in order to obtain realistic population distributions for a rectangle and also so that the consumption values within a rectangle can be classified according to city and country (Section 2.2.2).

The following data is required as input data for calculating the structure of a certain surface element, in addition to the geographic latitude, for governmental districts which overlap the rectangle with a given surface area:

- Total number of inhabitants
- Total surface areas
- Surface fraction of the governmental districts which make up the surface element,
- City inhabitants,
- City surface area (total surface area and partial surface area).

Using this data, one determines the city and country population fractions of each governmental district which is superimposed on to a surface element, by forming the sums and the ratios, and in this way the total population

distribution of each rectangle is established.

2.4. Consumption data

The basis for distributing the consumption data among the governmental districts (initial variables) for the years 1960 to 1980 is the basic data and estimation values in five-year intervals, which have been established by institutes of market research (for example, German Institutes for Economic Research DIW, Berlin). The current forecasting method as well as special assumptions made for the large area surveys considered here (for example, fractions of individual and collective heating units, f in Equation 2), are discussed in Section 3.

The consumption values for the 70 rectangles are established using the consumption data of the governmental districts of initial variables and the population data (Section 2.3) as distributing variables. The principle used is discussed in the following.

2.4.1. Household and small-scale consumption

The initial values of the governmental districts BV_R are related separately to the population number E_R for the fuels coal, oil and gas. In this way the inhabitant-specific consumption of a certain governmental district is defined as follows

$$bv = \frac{BV_R}{E_R} \tag{6}$$

The population number E'_R for the fraction of a governmental district which is superimposed on to a rectangle is known (Section 2.3), so that with the bv value of the same governmental district, it is possible to establish the consumption fraction BV'_R, which can be attributed to the rectangle under consideration:

$$BV'_R = bv \cdot E'_R \cdot \tag{7}$$

For the rectangle under consideration, we then sum up the component consumption values from the superimposed government regions, so that for certain fuel types we find the following desired consumption value (see G. 2, Section 2.2.1):

$$BV_K = \sum BV'_R \tag{8}$$

2.4.2. Road traffic

We proceed similarly to what we did for the classification of the consumption data for the fuels gasoline and diesel oil. For a certain fuel, the consumption for inhabitants for a certain governmental district is given as

$$kv = \frac{KV_R}{E_R} \cdot \tag{9}$$

Since the differences in driving methods for city traffic and rural traffic must be considered (Section 2.2.2), therefore, the city consumption KV'_{SR} as well as the rural consumption KV'_{LR} must be determined separately for the fraction of each governmental district which overlaps a rectangle. Using the city population numbers E'_{SR} and the rural population number E'_{LR} known for the governmental district (Section 2.3), it is possible to determine the consumption value parts as follows:

$$KV'_{SR} = kv \cdot E'_{SR} \tag{10}$$

$$KV'_{LR} = kv \cdot E'_{LR} \tag{11}$$

For the rectangle under consideration, the partial consumption values are summed up separately from the superimposed governmental districts, separated according to city consumption and rural consumption. For a given

fuel type we find the following city consumption values KV_{SK} and the rural consumption values KV_{LK} (see Equation 4, Section 2.2.2):

$$KV_{SK} = \sum KV'_{SR} \tag{12}$$

$$KV_{LK} = \sum KV'_{LR} \tag{13}$$

The total consumption of the fuel type within a certain rectangle of necessity must be the following

$$KV_K = KV_{SK} + KV_{LK}$$

2.5. Emission factors

The selection of the emission factors is relatively difficult because the state of knowledge in this area is not yet complete. An extensive literature search, and inquiries at institutes which are concerned with the problem of the determination of the emission factors, finally resulted in a number of emission factors which correspond to the state of knowledge of 1975 for the Federal Republic of Germany from the point of view of the fuels and installations. The calculation model is built in a flexible manner so that future technical developments can be considered in principle. However, we will not discuss this within the framework of the study mentioned in the introduction, if we disregard the indirect consideration of the trend of an increase of collective heating units compared with the assumption of individual heating units, which we will discuss later on (Section 3.2 and 3.3). On the other hand, time dependent changes in the emission factors are included which are the result of changes in the laws.

In the following, we will discuss in more detail which parameters are considered and what assumptions were used to select the emissions for developing the calculation model. Here we will not give any quantitative values which would go beyond the scope of this report. We would like to mention the report discussed at the beginning for this purpose.

2.5.1. Household and small scale consumption

Starting with the heading parameter "contamination agent", we have emission factors for the following contamination agents:

- Sulfur dioxide
- Nitrogen oxide
- Hydrocarbon
- Carbon monoxide
- Solid material (soot)

For a given contamination agent, the emission factor depends among other things on the following:

- Heating type

  -- Single heating unit
  -- Collective heating unit

- Heating installation type or fuel type

  -- Solid (rock coal, brown coal, coke)
  -- Liquid (oil)
  -- Gaseous (natural gas, etc.)

Basically, when specifying the emission factors for the solid fuels, we assume that primarily coke is used for collective heating units. In the case of single heating units, an average emission factor for "coal" is selected which was calculated using a percentage distribution of rock coal/brown coal during the use of single heating units for the years 1960 to 1980 (Section 3). This means that in the latter case, the emission factor depends on time.

In the case of the emission factors for liquid and gaseous fuel types, according to present day knowledge, no unique distinction can be made with respect to an individual heating unit and collective heating units, but only with respect to fuel type. When establishing an emission factor for liquid fuels, the legally binding stepwise decrease of the sulfur content in light heating oil and diesel fuel after 1976 is considered (3. Regulations for the Execution of the Federal Immission Protection Law; 1975), which again results in a time variation of the emission factor (Section 3).

2.5.2. Road traffic

If we again start with the heading parameter "Contamination agent", then the emission factors are available for the following contaminants:

- Sulfur dioxide
- Nitrogen oxide
- Hydrocarbon
- Carbon monoxide
- Soot
- Lead

For a given contamination agent the emission factor depends on the following among other things.

- Vehicle type
  - -- car
  - -- truck
- Fuel type
  - -- Gasoline
  - -- Diesel oil
- Driving style

-- Average velocities for city use of cars and trucks
-- Average velocities for rural traffic for cars and trucks

In order to establish the emission factors we basically assume that the cars were operated exclusively with gasoline and the trucks were operated exclusively with diesel fuel. In this way we obtain four emission factors for each contamination agent considering the driving styles.

The following legal requirements were considered (Section 3.3):

- 3. Regulations for the execution of the Federal Immission Protection Law; 1975 (Reduction of the sulfur content in light heating oil and diesel fuel).

- Gasoline-lead law; 1971 (stepwise reduction of lead content in gasoline)

- Low traffic authorization law (StVZO, Section 47, Appendix XIV); in the version of November 15, 1974 (Reduction of CO and C_mH_n emissions for cars in city traffic)

- Change in the road traffic authorization law; 1975, Printed matter No. 181/75 (further reduction of CO- and C_mH_n Emissions for trucks in city traffic

2.6. Calculation sequence and results

In order to calculate the structural and consumption data (Sections 2.3 and 2.4) as well as the emission data (Section 2.2) for the rectangles, we built an EDP program. Figures 3 and 4 show the flow diagrams with similar structure for the emittent groups household consumption and small scale consumption, as well as for road traffic. This intentional analysis together with a unified collection of the input data, made the building and sequence of the program simpler. The input data, which were prepared for

the governmental districts, are punched on to four punched cards (KA1 to KA4; Table 1). The correspondence can be seen from Figures 3 and 4. The preparation of the input data, which under some conditions makes it necessary to treat the data on a Federal state plane (Section 3), is done manually (indicated in Figures 3 and 4 by means of dashes).

TABLE 1. EXPLANATION FOR THE CARD TYPES OF INPUT DATA FOR THE RECTANGLES

Card type	Read in quantities
KA 1	Governmental district, the year, population, surface area, consumption: - Coal - Oil - Gas - Carburetor fuel - Diesel fuel
KA 2	Governmental district, geographic position of rectangle. (Right-hand value/top value), city inhabitants, city surface area, city name
KA 3	Geographic position of the rectangle (Right-hand value/top value), Governmental district, area fraction of the Governmental district with respect to the rectangles
KA 4	Specific emission factors of the contamination agents SO_2, NO_x, C_mH_n, CO, soot, lead: - Consumer type (coal, oil, gas, carburetor and diesel fuel) - Heating type (single heating unit/collective heating unit) - Fuel consumption type (city/rural consumption) - Year - Percentage division according to heating type

The computer output is done in the form of tables and their external form corresponds approximately to a map of the Federal Republic of Germany. The results of the individual rectangles are printed out in the field of the table, which corresponds to the geographic position of the rectangle (see also Figure 1). For each rectangle, the following data are printed out in two table types each for each of the two emittent groups:

- Household and small scale consumption

  -- Emissions for coal firing units
  -- Emissions for oil firing units
  -- Emissions for gas firing units
  -- Total emission

  } Separated according to contamination agents and 5-year intervals (1960, 65, 70, 75, 80); Table type 1

  -- Time trend (1960 to 1980) of the development of the total emissions for each contamination agent; Table type 2

- Road traffic

  -- Emissions from internal combustion engines (cars)
  -- Emissions from diesel motors (trucks)
  -- Total emissions

  } Table type 1

  -- Time trend (1960 to 1980) of the development of the total emissions; Table type 2

Table 2 gives an example for Table type 2, a printout for the contamination agent nitrogen oxide for the household and small scale consumer areas. In addition, the total emissions of both emittent groups can be superimposed. Also it is possible to print out the structural data, as well as the consumption data for each rectangle in the manner discussed above.

TABLE 2. EXAMPLE FOR A COMPUTER PRINTOUT OF "TABLE TYPE 2"; EMITTENT GROUP: HOUSEHOLD AND SMALL SCALE CONSUMPTION: CONTAMINATION AGENT: NITROGEN OXIDE (t/km^2 AND YEAR)

			0.330	1960		
			0.498	1965		
			0.511	1970		
			0.552	1975		
			0.674	1980		
			0.300	0.470		
			0.452	0.709		
			0.464	0.728		
			0.500	0.785		
			0.611	0.959		
	0.284	0.745	0.692	1.125		
	0.451	1.187	1.003	1.612		
	0.498	1.298	1.102	1.768		
	0.567	1.554	1.168	1.854		
	0.571	1.465	1.473	2.415		
	0.278	0.781	0.242	0.250		
	0.441	1.247	0.374	0.390		
	0.487	1.356	0.416	0.429		
	0.555	1.660	0.466	0.481		
	0.558	1.523	0.494	0.508		
	0.231	0.306	0.239	0.224		
	0.365	0.486	0.380	0.355		
	0.404	0.537	0.420	0.392		
	0.460	0.611	0.478	0.447		
	0.462	0.613	0.480	0.448		
	0.376	0.636	0.787	0.642		
	0.602	1.017	1.251	1.018		
	0.691	1.170	1.388	1.128		
	0.732	1.236	1.569	1.284		
	0.738	1.245	1.577	1.282		
0.802	1.470	0.566	0.410	0.364		
1.289	2.365	0.911	0.656	0.578		
1.506	2.762	1.064	0.743	0.640		
1.544	2.832	1.090	0.811	0.729		
1.557	2.856	1.100	0.817	0.730		
2.209	2.175	0.301	0.326			
3.551	3.497	0.490	0.545			
4.149	4.086	0.577	0.650			
4.255	4.188	0.592	0.678			
4.287	4.220	0.598	0.692			
1.198	0.805	0.384	0.267			
1.924	1.306	0.639	0.452			
2.246	1.517	0.742	0.529			
2.305	1.632	0.757	0.530			
2.322	1.603	0.769	0.546			
0.257	0.430	1.025	0.376	0.325	0.327	
0.429	0.730	1.773	0.635	0.510	0.479	
0.493	0.840	2.188	0.746	0.545	0.550	
0.587	1.060	2.305	0.772	0.585	0.574	
0.549	0.968	2.474	0.826	0.610	0.597	
0.343	0.390	0.684	0.426	0.318	0.337	0.205
0.570	0.656	1.185	0.696	0.486	0.502	0.314
0.645	0.746	1.438	0.776	0.541	0.577	0.357
0.768	0.921	1.591	0.846	0.583	0.612	0.363
0.723	0.847	1.569	0.857	0.618	0.645	0.366

TABLE 2 (CONTINUED):

1.233	0.793	0.899	0.507	0.328	0.552	0.246	
1.970	1.305	1.489	0.844	0.508	0.837	0.379	
2.168	1.461	1.757	0.985	0.591	0.970	0.427	
2.172	1.654	2.063	0.974	0.636	1.067	0.440	
2.279	1.604	1.928	0.940	0.689	1.165	0.442	
		0.493	1.010	0.357	0.247	0.233	0.200
		0.806	1.695	0.596	0.415	0.359	0.308
		0.936	1.949	0.673	0.486	0.400	0.343
		0.943	1.812	0.661	0.543	0.425	0.365
		0.899	1.759	0.671	0.577	0.422	0.363
	0.509	0.311	0.372	0.367	0.865	0.210	
	0.822	0.505	0.612	0.617	1.561	0.360	
	0.947	0.560	0.672	0.672	1.900	0.426	
	0.851	0.499	0.603	0.697	2.190	0.481	
	0.813	0.475	0.577	0.736	2.340	0.503	
	0.379	0.314	0.357	0.280	0.233	0.249	
	0.613	0.507	0.583	0.473	0.420	0.449	
	0.706	0.581	0.641	0.519	0.512	0.548	
	0.634	0.522	0.580	0.544	0.591	0.632	
	0.607	0.499	0.559	0.575	0.631	0.676	

2.7. Improvement of the resolution of the methodology

The methodology discussed up to the present can certainly be used for a large area, that is over-regional surveys of emissions, as well as for analyses of trend developments. Even for regional surveys, the method still has some information capacity, but in this case the resolution achieved with this methodology will be considered to be too coarse. Therefore, we modified the existing methodology for the emittent groups of road traffic, so that the information content of the results would be increased for regional surveys. The principle of these modifications is outlined in the following. For the emittent groups of the household and small scale consumption, there is not yet a corresponding refinement of the methodology, but it is certainly possible.

The resolution is improved by dividing each of the existing surface elements (approximately 55 km · 70 km) by means of lines separated by six latitude minutes and 10 longitude minutes into 30 partial surfaces, each about 10 km · 11 km. This then corresponds to conventional topographic maps

(Scale 1 : 25,000). For these partial surfaces it was necessary to determine the structural and consumption data.

In order to determine the structural data, we use the same principle discussed in Section 2.3. As a result of this, for each of the surface elements we then have the city inhabitant component and the rural inhabitant component, which is required to determine the consumption values as distribution data.

The distribution of the consumption data is refined to the extent that for each field type and vehicle type the consumption is not only separated according to the city fractions and rural fractions, but also the consumption on Federal high speed roads (Federal autobahns and Federal roads) is considered. This fuel consumption is calculated from the traffic numbers on the Federal high-speed roads and the corresponding average fuel consumption per vehicle type. Traffic concentration maps are the basic data for determining the traffic performance, separated for the amounts of cars and trucks.

This additional consideration of the fuel consumption on high speed Federal roads necessitates one to consider a third driving style when establishing the emission factors. By introducing the latter, the differences in driving cars and trucks (consideration with the assumption of the average velocities), on Federal high speed roads are taken into account.

With this modification of the methodology, which requires a justifiable additional effort of computation, the resolution of the results is considerably enhanced so that it seems justified that the large area survey methods for emissions can be applied in the regional plane as well.

3. FORECASTING METHODOLOGY USED

3.1. General remarks

According to a simplified initial equation for calculating the emissions for a certain contamination agent (Equation 1), the following variables will depend on time, for example, in the trend analysis, i.e., when forecasting emissions:

- Consumption
- Emission factor

As already indicated (Section 2.5), in the present methodology of large area forecasting of emissions, we consider the future development of the emission factor almost only when its future value is indeed known (for example, when the actual state is established, the future legal data is already known). On the other hand, the consumption for future years must be forecast in the original sense, i.e., current extrapolation methods must be used. Accordingly, the present chapter is divided into the treatment of predicting the consumption (Section 3.2) and the treatment of the determination of future emission factors (Section 3.3).

Basically, the following global classifications can be made of currently used forecasting methods:

-Finding of ideas (for example, brainstorming)
-System analysis (for example, cost-use analysis)
-Trend analysis (for example, central time series)
-Expert interviews (for example, Delphi interviews)
-Simulation (for example, mathematical models)

These forecasting methods must be looked upon as tools which themselves do not give any useful forecast. Instead, one will always be forced to combine various methods depending on the requirements, whereas for each case

the emphasis will lie with one or another method. One can say without a doubt that in the determination of consumption, trend analysis dominates according to the present state of knowledge. On the other hand, when forecasting emission factors, expert interviews and/or system analysis are most important, which is often true for the case of consumption forecasting in connection with one or all of the other methods.

3.2. Consumption data

As already mentioned in Sections 2.4 to 2.6, as initial data (= input data for the computer model) we require the consumption data on the government district plane in 5-year intervals (1960 to 1980). Whenever possible, we will use values which have been established by market research institutes (for example, German Institute for Economic Research, DIW, Berlin). The forecasting methods used there will be discussed in Section 3.2.1 (available data). The method used to complement the missing data, i.e., the establishment of the final initial data used as input for the computation model, is discussed in Section 3.2.2.

3.2.1. Available data

3.2.1.1. Household and small-scale consumption

For calculating the consumption of a certain fuel for a given region (for example, governmental district) we use the following initial equation for the forecasting method applied here:

$$BV = W \cdot b, \tag{15}$$

where

BV absolute fuel consumption,
W apartment inventory and
b fuel consumptiona per apartment

The future absolute fuel consumption depends on the development of the regional apartment inventory and the future fuel consumption per apartment. The number of apartments itself also depends on the development of the absolute population numbers and the number of persons per apartment. Other influencing factors, for example, the development of the income for the support of building activity, are not considered. The fuel consumption per apartment also depends on the future temperature development. Therefore, we obtain the following quantities which must be established:

- predicted development of population numbers
- predicted development of number of persons per apartment
- predicted temperature development
- predicted development of fuel consumption per apartment

Trend analysis is used as a forecasting method. One assumption for its use is that for certain time intervals (basic time interval), basic data are available, i.e., known statistical material. For the basic time interval (8 to 10 years) the data material is reviewed and some of the influences are removed which could distort the trend. Two of these influences which are considered are the external temperature and the changes in reserves.

In order to remove the influence of external temperatures from the fuel consumption, we select the degree - day as a unit of measure. The degree - days were calculated from the number of heating days (external temperatures smaller than 12° C), multiplied by the difference between the reference temperature (19° C, average temperature in living rooms) and the average monthly external temperature. For this basic time period, the average fuel consumption per apartment $b = BV/W$ as well as the absolute fuel consumption of the regional unit depend on the time t (trend) and the external temperature T (degrees-days) as well as the reserve changes, which are assumed to be constant at that time. Using a linear multiple regression equation of the form

$$b = a_o + a_1 t_1 + a_2 T, \tag{16}$$

in which the temperature influence as well as the time change b are considered, we can take out the influence of temperature. The coefficients a_o to a_2 are determined from the basic data. From the Equation (16), we then substitute the average temperature values (here: 3042 degrees-days average for the time period 1881 - 1940), then from this we can determine the fuel consumption per apartment which would have occurred in the basic time period for normal weather conditions.

The absolute consumption over the basic time period from which the temperature influences have been removed is then found according to the Equation (15). As an example Figure 5 shows the non-temperature compensated fuel consumption problems for Niedersachsen and Baden-Württemberg, and Figure 6 shows the temperature-compensated absolute fuel consumption for Hessen and Bayern.

As far as the reserve changes are concerned, one must realize that the available statistical material only represents the deliveries of energy supplies, not the consumption itself. This means that between buying of the fuels and their consumption, time shifts can occur which among other things depend on the capacity of the users to store the fuels. Statistical analyses, however, show that the influence of reserve changes is less than 5% and therefore can be ignored.

After preparation of the basic data one can start with the stepwise forecasting calculation. Using the basic data, regression equations are established for the various relationships, which are tested for validity using their degree of certainty or their correlation coefficients. The general forecasting procedure is shown in Figure 7.

The second quantity for determining the apartment inventory (Equation 15) is the number of persons per Apartment P which is defined as follows:

$$P = \frac{\text{Inhabitants in the governmental district}}{\text{Number of apartments in the governmental district}} \qquad (17)$$

The development of these variables of the basic time period is investigated using linear, exponential and logical functions, and the latter have the highest measure of certainty. The degressive trend of the number of persons per apartment established in the time variation of the basic data is used as a basis for the forecasting calculation.

Using the time variable "number of inhabitants" and "number of persons per apartment" we can calculate the future apartment inventory W for each governmental district as follows:

$$W = \frac{\text{Future number of inhabitants}}{\text{Future number of persons per apartment}} \qquad (18)$$

In this way we have the first variable for determining the future absolute fuel consumption (Equation 15). Before we can forecast the second quantity, that is, the average fuel consumption per apartment, we must make a statement regarding the external temperature during the forecasting time period. Basically we assume that it is not possible to make a forecast about the future external temperatures. Therefore, just the basic data were compensated for temperature, and we assume that for the time period between 1841 and 1940 that the determined degree-day value is representative for the forecasting time interval as well. When determining the regional average degree-day values, we run into difficulties because the 38 governmental districts are all represented by 26 temperature measurement regions of the German weather service. Since an average degree-day value must be determined for each governmental district, regional correction and intersections are required in a few cases.

Using Equation (16) we now calculate the average fuel consumption per apartment for the forecasting time interval. However, we should note here that the data required was only available for the federal states and not for the governmental district plane. In order to project the average fuel consumption in the governmental districts, it is assumed that deviations of the average value of a governmental district from the average value of the

corresponding state are so small that the values which apply for the federal states can be transferred to the corresponding governmental districts.

Using the apartment inventory W on the average fuel consumption b, it is now possible to determine the absolute consumption of a certain fuel for a given governmental district over the forecasting time interval using Equation (15). Figure 8 shows an example of the time change of the consumption of solid, liquid and gaseous fuels during the basic time period and the forecasting time period for the Oberbayern governmental district.

Figure 8 clearly demonstrates one of the boundary conditions which is the basis of the forecasting method used here. This is the assumption that the consumption of solid fuels decreases over the forecasting time interval under consideration, whereas the consumption of liquid fuels will increase. Of course it is difficult to make a statement about the accuracy of such forecasts. For one thing, these depend on the accuracy of the basic data, which in the case discussed should be relatively secure. In addition, the assumptions about the future trend have a strong influence, of course. In the present case we may at least state that after the reversal point (basic data projection; Figure 8), we do not find the same increase or decrease rate for the projection of the consumption values which would be the simplest method of extrapolation, except for linear extrapolation.

This means that here at least a relatively good projection has been made, at least from a qualitative point of view.

We are now faced with a question as to how such forecasts which were based on trend analysis can be tested. Basically we will have to restrict ourselves to one or several qualitative methods. In the second case we used three possibilities which led to satisfactory results:

- Testing of the regional results by a global projection for the entire Federal Republic
- Testing of the forecasting results using the supply possibilities of the individual energy sources

- Testing of the forecasting results using future price predictions

The example of the oil prices shows very drastically how a forecast can be influenced by external and unpredictable influences. Without consideration of this event, the assumption of a linear increase of the average fuel consumption per apartment is entirely justified; however, the assumption at the present time would have to lead to consumption rates which lie close to the upper limit. However, if we consider the fact that more recently the increased price, for example, for light heating oil, represents a nonexpected burden for each consumer, we can assume that the consumers will attempt to save energy. In order to consider this influence, it seems to be fairly justified to assume that the average fuel consumption per apartment will remain constant in the future. Using this assumption we obtain total consumption values which lie at the lower limit of the expected consumption rates compared to the calculation given above. This difference, for example, for the total energy consumption of the household sector of the Baden-Württemberg state for the year 1980 is about 25%. This example shows that the safety of the forecast does not only depend on the quality of the basic data, but can be influenced greatly by external influences which cannot be immediately checked and can lead to deviations of the order mentioned above. This fact is not supposed to reduce the value of the forecasting methods discussed here, but should only clarify the requirement for limit value analysis.

3.2.1.2. Road traffic

We have given a relatively complete description of the forecasting method for the household and small scale consumption sector as well as the associated problems. In the following we will give a short outline of the methodology developed for road traffic. Basically the consumption must be forecast separately for carburetor fuels (gasoline) and diesel fuels (Section 2.2.2).

The carburetor fuel consumption can be determined methodologically as dependent on the following influences:

- Vehicle inventory
- Specific fuel consumption =
  average fuel consumption per vehicle type

The development of the fuel reserve again depends on

- Vehicle density (cars per 1,000 inhabitants)
- Population

In addition, the average fuel consumption is influenced by

- Composition of piston volume class
- Driving performance per vehicle
- State of road development

The forecast for fuel consumption is done in steps according to the following pattern (Figure 9), whereas at least 10 years are used as the basic time frame: the vehicle inventories in the governmental districts of a certain Federal State are directly extrapolated (Forecast A), so that the regional structuring results. At the same time the vehicle density and the population for the Federal State are forecast (Forecast B). The vehicle inventories which are the result of Forecast B are used as specified values. The structure of the inventories determined in Forecast A in the governmental districts is referred to them. Using the vehicle inventories, now known for the governmental districts, and the specific forecast fuel consumption (Forecast C) forecast directly for the Federal State, one obtains the future carburetor fuel consumption for each governmental district of the Federal State under consideration. Figure 10 gives an example of the trends of the vehicle inventory, specific fuel consumption and absolute carburetor fuel consumption, i.e., the last three steps of the overall forecast for the governmental district Nord-Württemberg. The example

is from a DIW forecast, made in 1970.

This forecast was made with certain assumptions which are partly evident from Figure 10 as well:

- The specific consumption which was also calculated for the Federal State can be transferred to the governmental districts;
- The specific consumption is subjected to a slightly increasing tendency between 1970 and 1980;
- The traffic which crosses the state boundaries was not considered;
- The regional commercial structure has not changed;
- The final result depends greatly on the reliability of the population forecast.

We will now discuss two additional influences on the reliability of the overall forecast. First of all the assumption of the degree of saturation of the vehicle inventory is critical, because it can only be determined with difficulty from the basic data and depends on numerous economic influences, some of which can only be determined with difficulty. The second critical factor is the future development of the specific fuel consumption, which among other things depends on the driving performance and the piston volume class structure. In both cases many considerations influence the forecast calculation, which can only be specified numerically with difficulty. Therefore, similar to what was done in part for the household and small scale consumption, here again we will have to attempt to formulate upper and lower limits. For example, it is assumed to be quite realistic to assume that the lower limit of the degree of saturation is about 8% lower than the upper limit. In the case of the specific consumption, the lower limiting value can be about 9% lower. If one carries out the forecast calculation for the absolute carburetor fuel consumption with the limiting values, then for example for 1980, the difference between the upper and lower limit of the absolute consumption can amount to about 14%. Obviously in the case of emission forecasts, one will tend to select the upper limiting value.

The forecast of the diesel fuel consumption can also be applied with a methodology which is similar to the case of the determination of the carburetor fuel consumption. However, in this case basic data on the vehicle density on the Federal State plane is difficult to obtain and the inventories of vehicles driven by diesel fuel within the Federal State are forecast directly (Figure 11). Basically the same assumptions and restrictions apply for this method as were specified for the forecast of the carburetor fuel consumption.

3.2.2. Initial data

The first step for determining the initial quantities on the governmental district plane, required to calculate the individual consumptions in the rectangles (Sections 2.4 and 2.6), consists of putting together heating fuel and fuel consumption on a Federal plane, for the time period between 1960 to 1980. Table 3 gives a summary on the available material. We encounter the following difficulties:

- Information on all heating fuel and fuel consumption values are not available for every Federal state for the entire time between 1960 to 1980.
- In some cases only outmoded forecasts are available.
- Sometimes forecasts are available for a certain heating fuel or fuel consumption at two different points in time.
- Forecasts were not always prepared for the desired five-year intervals.

These difficulties are countered as follows: if the forecast has not been established for the desired yearly intervals (for examble, for 1960, 1964, 1968 ...), then the corresponding consumption values are plotted over time. The missing consumption values are interpolated for the five-year intervals. In the case where forecasts have been made at different points in time for a Federal State and for a certain type of consumption, the most recent extrapolation is accepted. Out of date forecasts are either not

TABLE 3. AVAILABLE STATISTICAL MATERIAL FOR HEATING FUEL AND FUEL CONSUMPTION OF THE FEDERAL STATE FOR THE YEARS 1960 TO 1980

Federal state	Heating fuel consumption															Fuel consumption									
	Coal					Oil					Gas					Carburetor fuel					Diesel fuel				
	60	65	70	75	80	60	65	70	75	80	60	65	70	75	80	60	65	70	75	80	60	65	70	75	80
Schlesw.-Holst.	x	x	x	x	-	x	x	x	x	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Hamburg	x	x	x	x	-	x	x	x	x	-	0	x	-	-	-	-	-	-	-	-	-	-	-	-	-
Bremen	x	x	x	x	-	x	x	x	x	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Niedersachsen	x	x	x	x	-	x	x	x	x	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Nordrhein-Westf.	x	x	x	x	x	x	x	x	x	x	0	x	x	x	x	x	$\bar{x}$	x	x	x	-	-	-	x	x
Hessen	x	x	x	x	x	x	x	x	x	x	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rheinland-Pfalz	x	x	x	x	-	x	x	x	x	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Baden-Württembg.	$\bar{x}$	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	x	x	x	x	-	x	$\bar{x}$	x	x
Saarland	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Bayern	x	$\bar{x}$	x	x	x	x	$\bar{x}$	x	x	x	x	$\bar{x}$	x	x	x	x	$\bar{x}$	x	x	x	x	$\bar{x}$	x	x	x

We have the following:

x Literature data available

$\bar{x}$ Interpolated value

0 Literature data available but not usable

- No literature data

considered or, if necessary, are used after certain corrections have been made to complement the existing material.

In cases where no data or no useful data is available for certain Federal States (Table 3), we proceed as follows: we start with the consideration that the population number is one parameter which is most important for determining the consumption. In the case of household and small scale consumption, the apartment inventory required for projection is determined from the population number (= population) and the average heating fuel consumption per apartment is determined (Section 3.2.1.1). In a similar way, when forecasting the fuel consumption, the population number has a great influence in the determination of the vehicle inventory (Section 3.2.1.2). In order to determine the consumption data which is missing for a few Federal States, we plot the data available for the time series as a function of the population numbers of the corresponding Federal states, separately for heating fuel and fuel types. Figure 12 gives an example of the relationship between the consumption of fixed heating fuels (coal) and the population number as a function of time. For each of the five years under consideration (1960, 65, 70, 75, 80) the corresponding trend is plotted in the form of a smooth curve. From these relationships the consumption values for most Federal States are found for which no data is available. Of course, in such a determination of the missing consumption data, under some conditions the influences of structural special features of the corresponding Federal States are washed out, for example, regionally different degree-days or regionally different vehicle densities. Considering the survey efforts, which would be required to consider such influences, the method used here is justified. Also these influences are represented again by the scatter of the available data for the Federal States, which are used to determine the trends mentioned above (see for example Figure 12).

The heating fuel and fuel consumption values classified regionally according to the regional districts, which finally are used as initial values in the computer program (Section 2.4 and 2.6), are then obtained as

follows: The data collected for the Federal States Schleswig-Holstein, Hamburg, Bremen and Saarland are used directly as initial data. If forecasting data is available for the various consumption values on the governmental district plane, then of course these are directly used as initial quantities in the computation model. The missing consumption data are distributed from the corresponding Federal State data to the governmental districts in a further step. The distribution is basically performed over the percentage population fraction of the corresponding governmental district of the total population of the corresponding Federal State. One disadvantage which must be accepted is to ignore the originally caused structural influences mentioned above (differences in degree-days, etc.).

One further case in which the initial data cannot be completely available is the following: forecasting data for a certain consumption, for example, are available for 1975 on the Federal State plane and the governmental district plane, but for 1980 it is only available on the Federal State plane. The consumption values of the regional district plane for 1980 are calculated from the Federal State consumption for 1980 using the percentage consumption fractions of the governmental districts in the Federal State consumption for 1975. This interpolation does not have the disadvantages of the method discussed above by a wide margin in which the population distribution is used to classify the consumption values.

One additional influence, which was not yet considered, for the household and small scale consumption, is the distribution of each heating fuel consumption among the use of the fuel by individual and collective heating units (Section 2.2.1). It is especially important to consider this influence because at the latest, since the oil crisis, the collective heating units have increased. The determination and forecasting of the distribution factors f_E for individual heating units and f_S for collective heating units are determined by the following considerations:

Individual ovens for solid, liquid and gas heating fuels are counted as individual heating units. Floor heating units, central heating units and remote heating units are considered separately according to the heating fuel used. As a basis for determining the distribution factors, a trend or development of the apartment inventory for the Federal Republic of Germany is selected given in the literature, which gives the distribution of individual and collective heating units for the years 1960 to 1970 (Figure 13).

Starting with this trend, the factors for the distribution of the heating fuel type among the individual and collective heating units are determined as percentages after the evaluation of various literature data. The result is shown in in Figure 14. We can distinguish the following trends from this:

- Increasing substitution of individual heating units for liquid and gaseous heating fuels by collective heating units
- Increasing substitution of the collective heating units for solid fuels (coal) by single heating units, which was a consequence of the trend of operating the collective heating units with liquid or gaseous heating fuels instead of solid heating fuels (Section 3.2.1).

The disadvantage of this forecast is that it applies for the entire Federal Republic. A forecast on the plane of the Federal States or governmental districts is not possible because of the missing statistical material.

3.3. Emission factors

As already mentioned in Section 3.1, the main emphasis of describing the forecasting method itself is the explanation of the trend analysis method used to predict the consumption values. These methods can only be used conditionally for predicting time changes in the emission factors, because technical changes of combustion installations or of fuels are not covered in this way, which would influence the emissions or the emission factors, respectively. The influences which are considered in detail will be discussed

in the following. These are the time changes of the emission factors which have been specified by legal regulations for the future, which are the result of changes in the installation and consumption structure. In part these time dependent changes were already mentioned in various previous sections. For completeness they will again be mentioned here.

Basically the time changes of the emission factors can be divided into:

- heating fuel or fuel dependent changes
- installation dependent changes

The following heating fuel or fuel dependent changes of the emission factors are considered:

- Changes of the coal consumption structure for individual heating units (rock coal/brown coal)
- Changes in the sulfur content in light heating oil and diesel fuel (3rd regulation for carrying out the Federal immission protection law, 1975)
- Changes in the lead content in carburetor fuels (gasoline lead law; 1971)

In the case of individual heating units, for the emissions from solid heating fuels ("coal") we establish an average emission factor for each contaminating agent (Section 2.5.1). For a certain year the percentage distribution of rock coal and brown coal was considered in the use of the individual heating units because the emission factors for brown coal and rock coal are considerably different. Therefore, for each year under consideration between 1960 and 1980 we calculated an average emission factor for each contamination agent and input this into the computer program, which takes this factor into account.

The change in the sulfur content in light heating oil and diesel fuel from 0.55 weight percent in the year 1975 , 0.50 in the year 1976 down to 0.30 weight percent in the year 1979, is considered in the calculation of the

emission factors for the contaminating agent sulfur dioxide for liquid fuels (household and small scale consumption) and for diesel fuel (trucks; road traffic; for the time period under consideration. In the same way, when determining the emission factor for lead in carburetor fuels (cars; road traffic) we consider the change in the lead content in gasoline, which after 1972 can only amount to 0.40 g/l and after 1976 can only amount to 0.15 g/l.

In addition the following installation dependent changes in the emission factors are considered:

- Changes in the structure of the heating type (individual heating units, selective heating units)
- Reduction of the emitted hydrocarbons and of the emitted carbon monoxide for cars because of changes in the road traffic acceptance regulations (StVZO, printed matter 181/75, 1975).

The change of the heating structure is not directly taken into account in the emission factors, but indirectly by introducing corresponding distribution factors (f_E and f_S) for the consumption value (Section 2.2.1). Section 3.2.2. already discussed how the distribution factors are determined for the time period between 1960 to 1980 under consideration.

The determination of the limitation of the contaminating agents hydrocarbons and carbon monoxide by the regulations of the StVZO is more difficult. We have the following initial situation: for cars built in the period 1972-1975 according to §47 StVZO upper limiting values for the emissions of hydrocarbons and carbon monoxide are specified. The emissions are determined as a function of the car test weight in experiments, in units of grams per test, and the European test cycle (city traffic only!) is assumed. According to the change in the §47 StVZO (printed matter 181/75) these limiting values will be reduced again for cars starting with the construction in the year 1976. From this it is found that for the time period of trend analysis between 1960 to 1970, the emission factors originally substituted for CO and C_mH_n (Sections 2.2.2 and 2.5.2) can be used. However, for the case "cars in city traffic" for 1975

new emission factors will have to be determined as well as for 1980. One proceeds as follows:

- The assumption of four piston volume classes (smaller than 1000 cm^3, 1000-1499 cm^3; 1500-1999 cm^3; 2000 cm^3 and larger).

- The assumption of a relationship from available statistical material which represents the development of the car inventory of the Federal Republic of Germany separated according to the four piston volume classes and with consideration of the three construction year groups (1960-1971, 1972-1975, 1976-1980) up to 1980. From this, one obtains the percentage composition of the car inventory according to construction years and piston volume classes.

- Establishment of a relationship between the piston volume and test weight, which establishes a relationship between the test weights specified in the StVZO and the car inventory, which is divided up according to piston volume classes.

- Establishment of a correspondence between the emission limiting values legally binding for 1975 and 1980, and the four piston volume classes.

- Conversion of the limiting values, which are given in grams per test, into grams per liter, where consumption data is required which was measured during the appropriate experiments with cars using the European test cycle.

With these data it is possible to calculate average emission factors for each of the contaminating agents in question and for each of the years 1975 and 1980. These are weighted according to the percentage fractions of the construction year and piston volume classes in the two years. Again we should point out that these emission factors only refer to emissions which are produced in city traffic by cars driven with carburetor fuels.

4. SUMMARY

We discussed a methodology with which it is possible to determine emissions for the emittent groups household and small scale consumption, as well as road traffic, on a large scale. It is also possible to establish future trend developments with it. The time period under consideration included the years between 1960 to 1980. The following contaminating agents were considered: sulfur dioxide, nitrogen oxides, hydrocarbons, carbon monoxide, solid materials (soot) and lead (only caused by road traffic).

In the first main part (Section 2) we discussed the structure of the computer model and its components, that is, the survey methodology. The model resulted in emissions for surface elements with dimensions 55 km · 70 km. This resolution can be improved to 10 km · 11 km, without increasing the data processing effort too much. In the second main part (Section 3), we outline methods which led to the determination of the time dependent input data (consumption values, emission factors) for the computer model, i.e., the forecasting methodology. We emphasize the description of the forecasting method with which the time trend of development of the consumption data was determined.

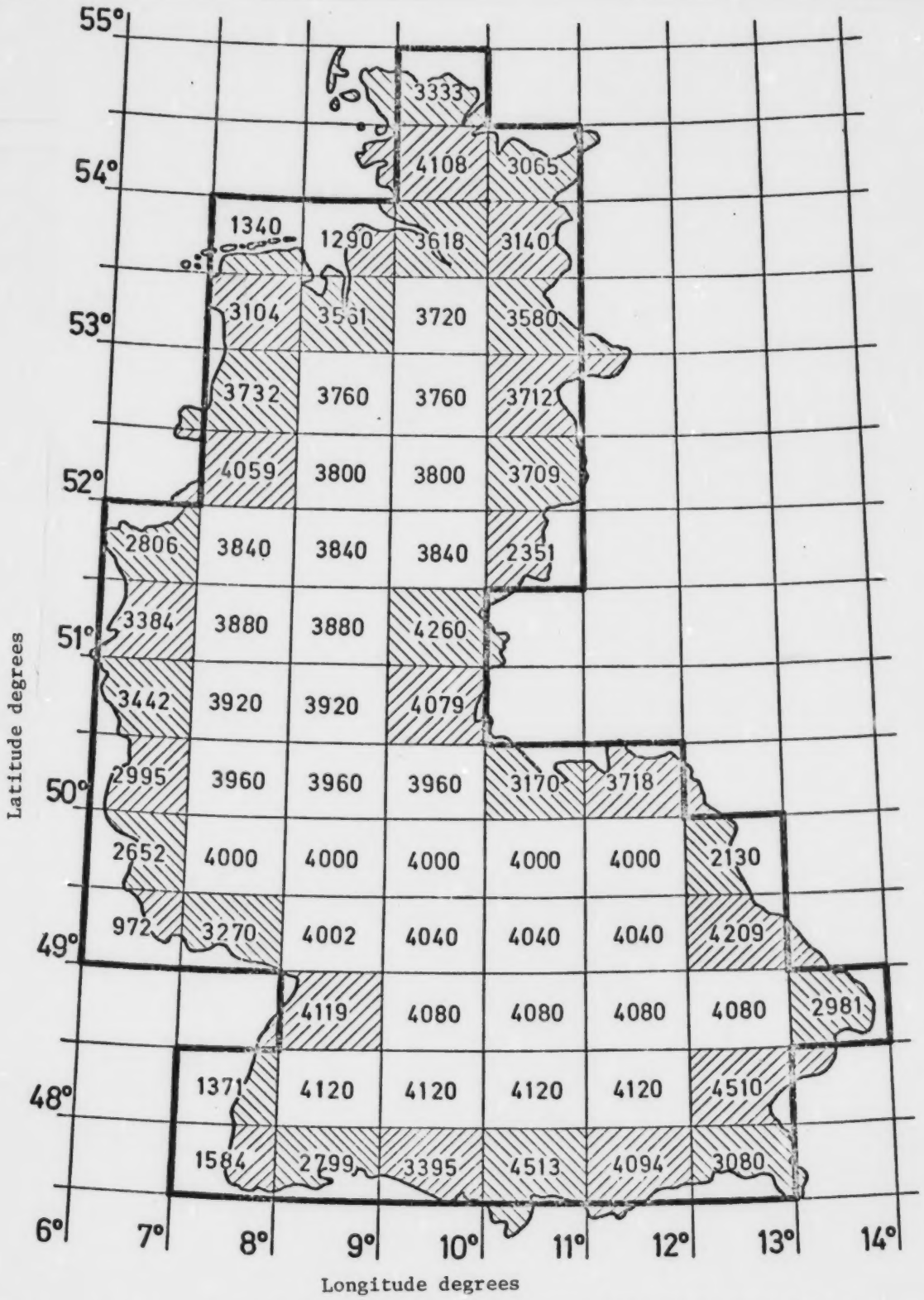


Figure 1. Division of the Federal Republic of Germany into rectangles (area data in km^2)

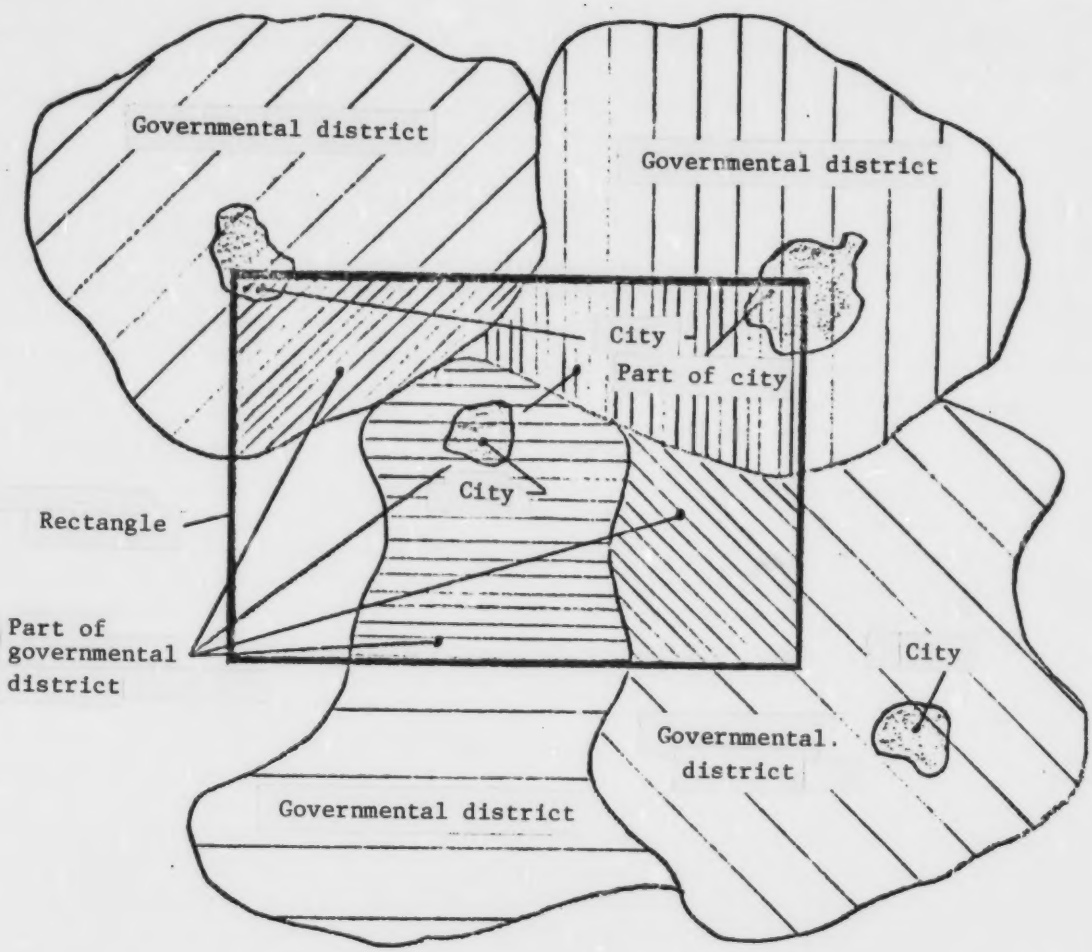


Figure 2. Schematic representation of the surface fractions of the governmental districts and cities in a rectangle.

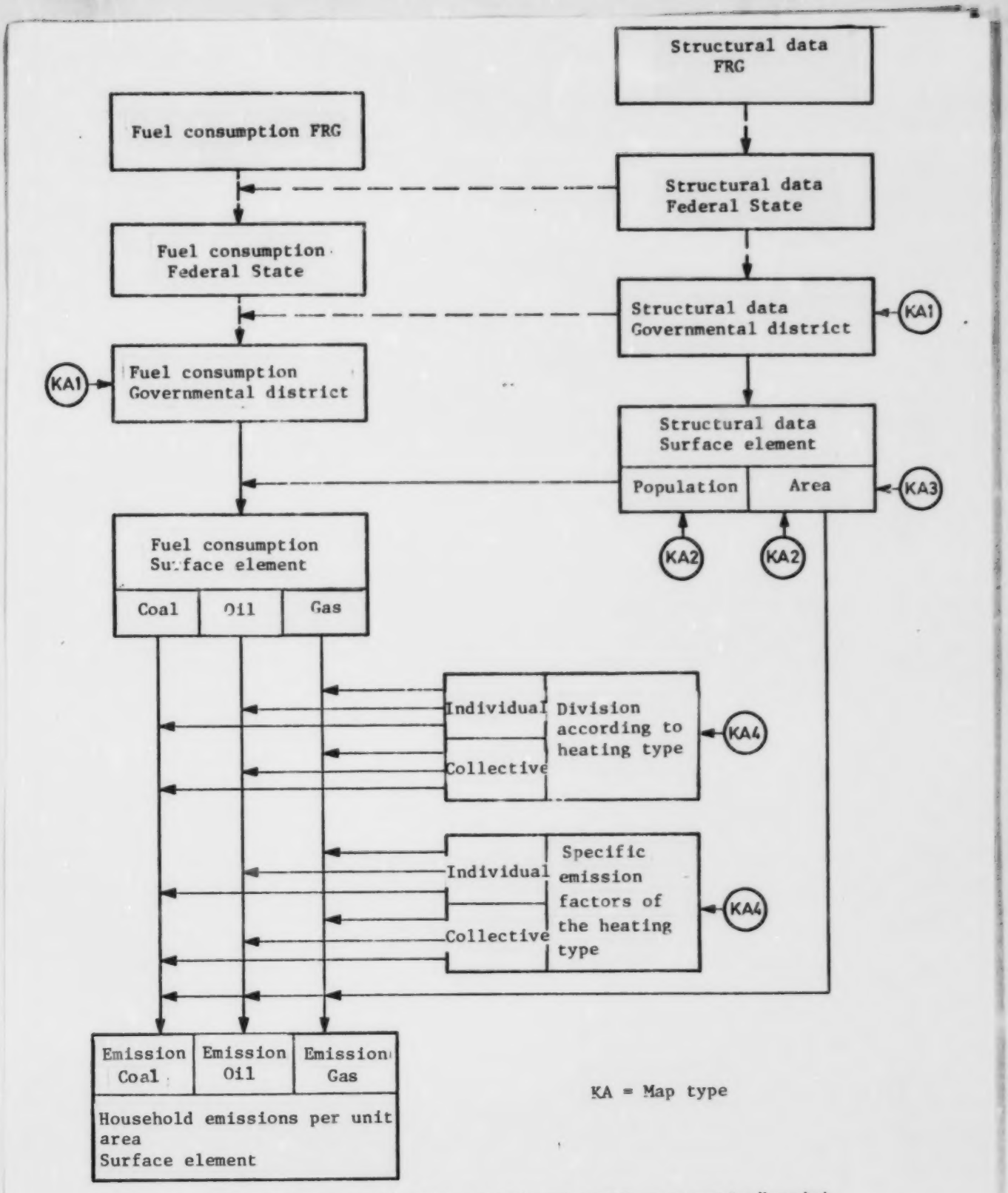


Figure 3. Flow diagram of the "household and small consumption" model.

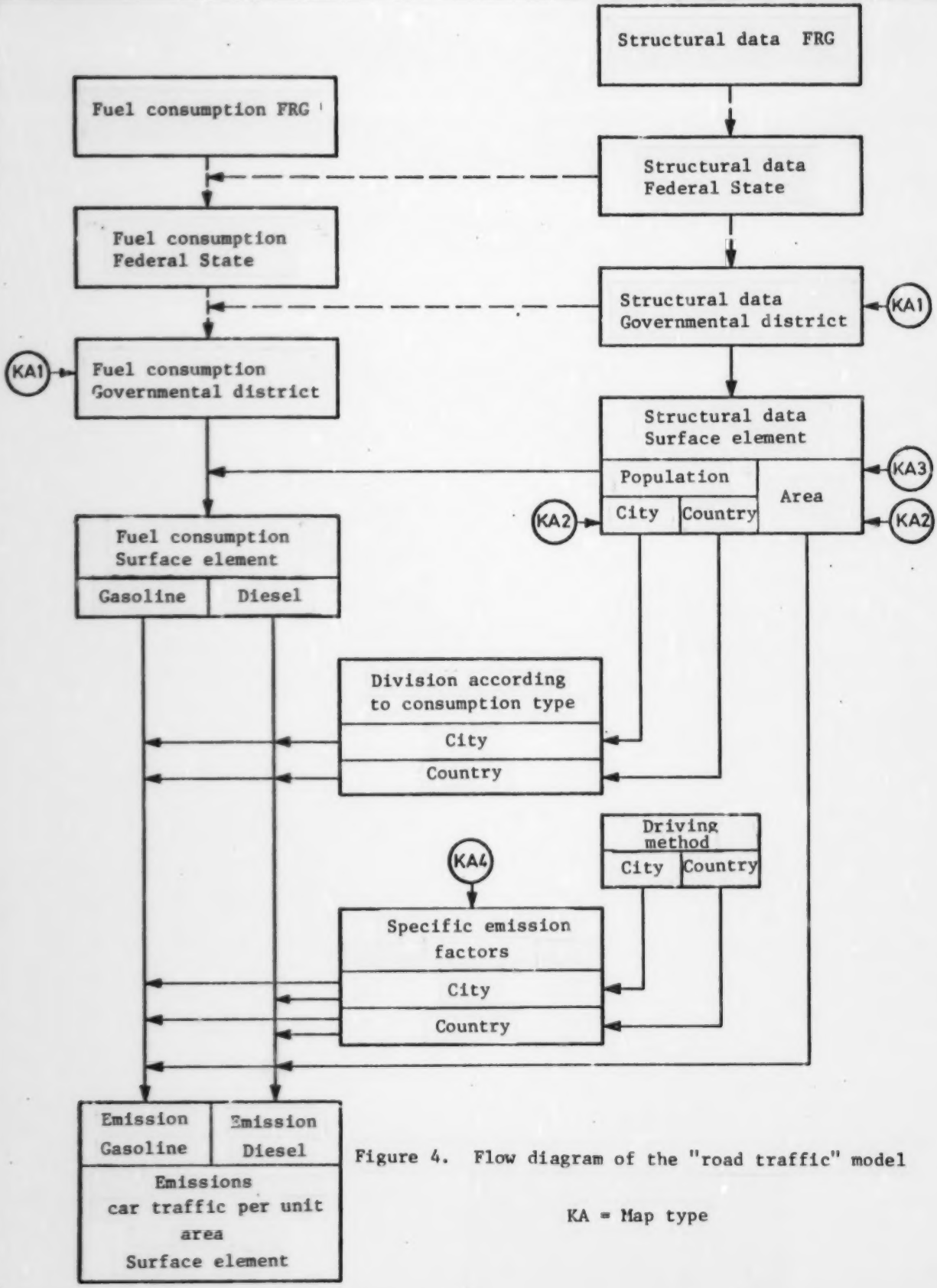


Figure 4. Flow diagram of the "road traffic" model

KA = Map type

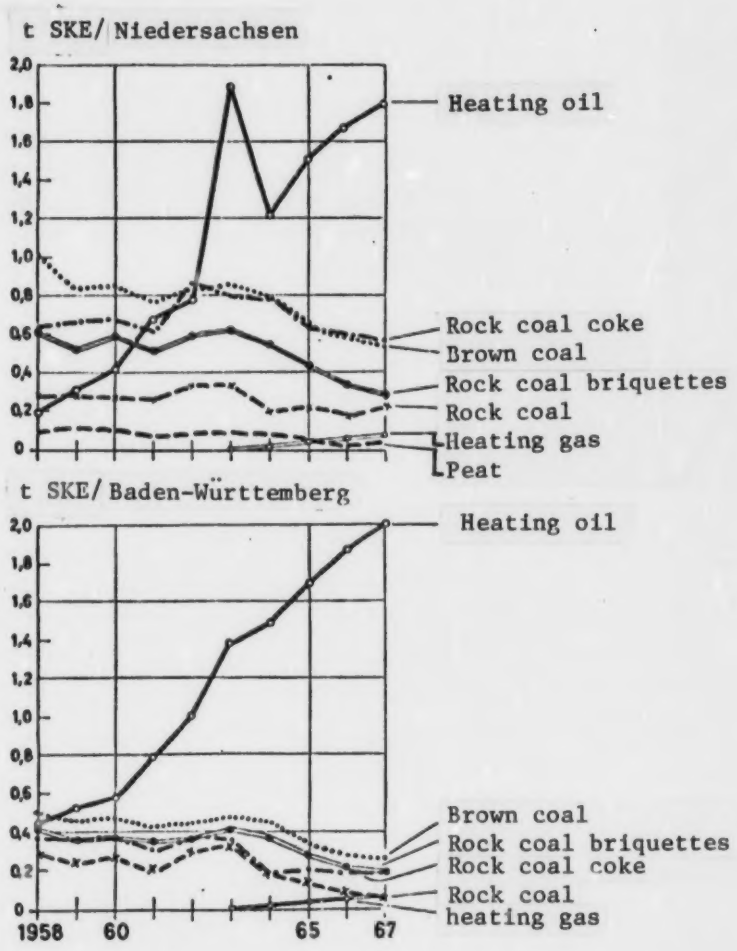


Figure 5. Average fuel consumption in Niedersachsen and Baden-Württemberg, 1958 to 1967 (according to DIW).

SKE = Rock coal equivalent $\triangleq$ 7000 $\frac{\text{kcal}}{\text{kg}}$
= Hard coal equivalent
5 = Tons, 1000 kg 1 t SKE = $7 \cdot 10^5$ kcal.

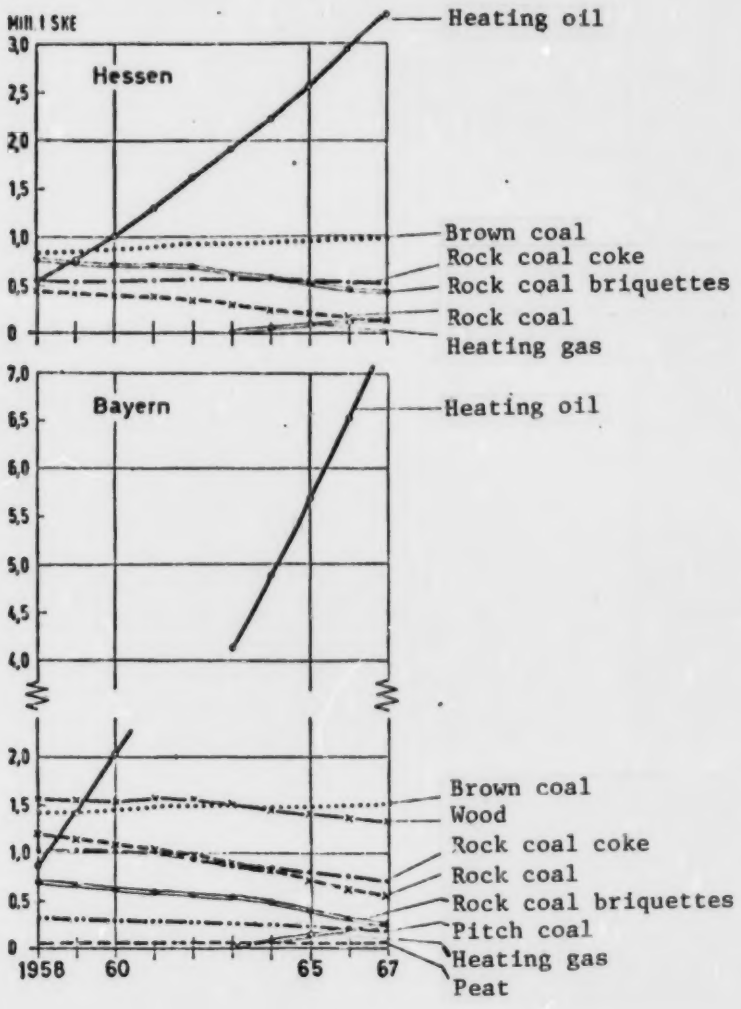


Figure 6. Temperature-compensated absolute fuel consumption in Hessen and Bayern, 1958 to 1967 (according to DIW).

Mill = 10^6

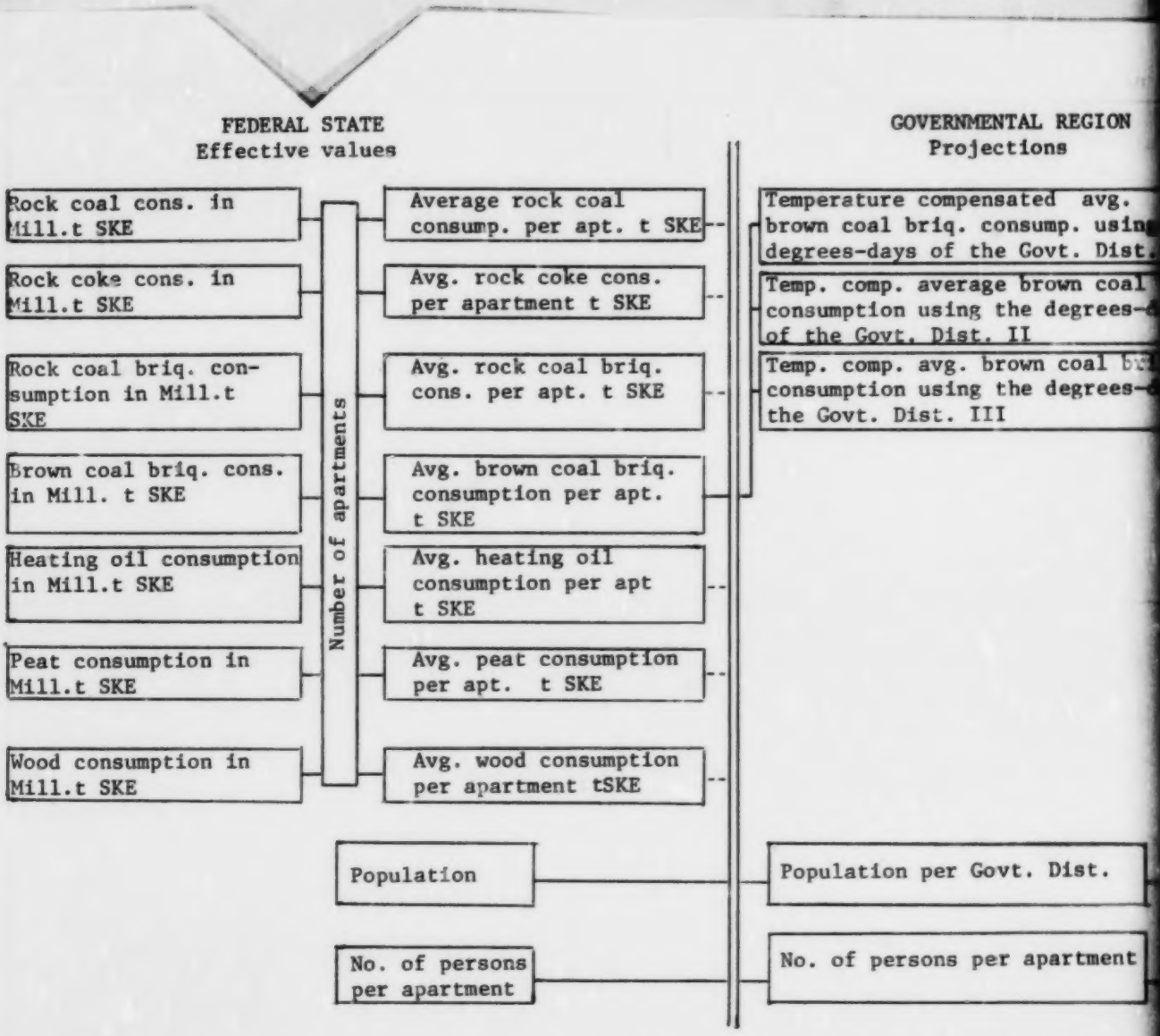
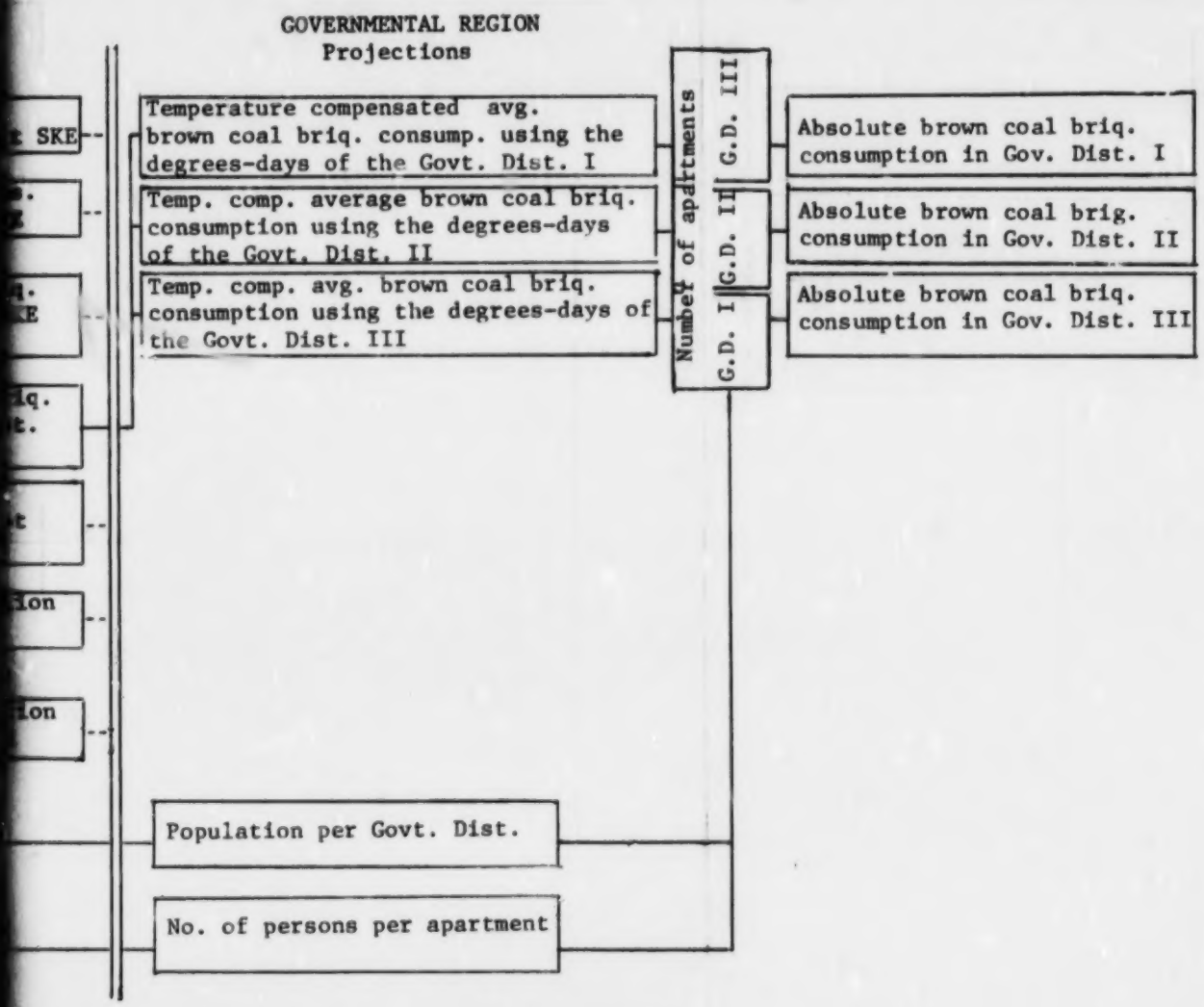

FEDERAL STATE
Effective values
GOVERNMENTAL REGION
Projections
Rock coal cons. in Mill.t SKE
Rock coke cons. in Mill.t SKE
Rock coal briq. consumption in Mill.t SKE
Brown coal briq. cons. in Mill. t SKE
Heating oil consumption in Mill.t SKE
Peat consumption in Mill.t SKE
Wood consumption in Mill.t SKE
Number of apartments
Average rock coal consump. per apt. t SKE
Avg. rock coke cons. per apartment t SKE
Avg. rock coal briq. cons. per apt. t SKE
Avg. brown coal briq. consumption per apt. t SKE
Avg. heating oil consumption per apt t SKE
Avg. peat consumption per apt. t SKE
Avg. wood consumption per apartment tSKE
Temperature compensated avg. brown coal briq. consump. using degrees-days of the Govt. Dist.
Temp. comp. average brown coal consumption using the degrees-d of the Govt. Dist. II
Temp. comp. avg. brown coal bri consumption using the degrees-d the Govt. Dist. III
Population
Population per Govt. Dist.
No. of persons per apartment
No. of persons per apartment

Figure 7. Diagram of forecasting methods for the temperature-compensated absolute fuel co (according to DIW).


GOVERNMENTAL REGION
Projections
SKE
Temperature compensated avg. brown coal briq. consump. using the degrees-days of the Govt. Dist. I
Temp. comp. average brown coal briq. consumption using the degrees-days of the Govt. Dist. II
Temp. comp. avg. brown coal briq. consumption using the degrees-days of the Govt. Dist. III
Number of apartments
G.D. III
G.D. II
G.D. I
Absolute brown coal briq. consumption in Gov. Dist. I
Absolute brown coal brig. consumption in Gov. Dist. II
Absolute brown coal briq. consumption in Gov. Dist. III
Population per Govt. Dist.
No. of persons per apartment

temperature-compensated absolute fuel consumption

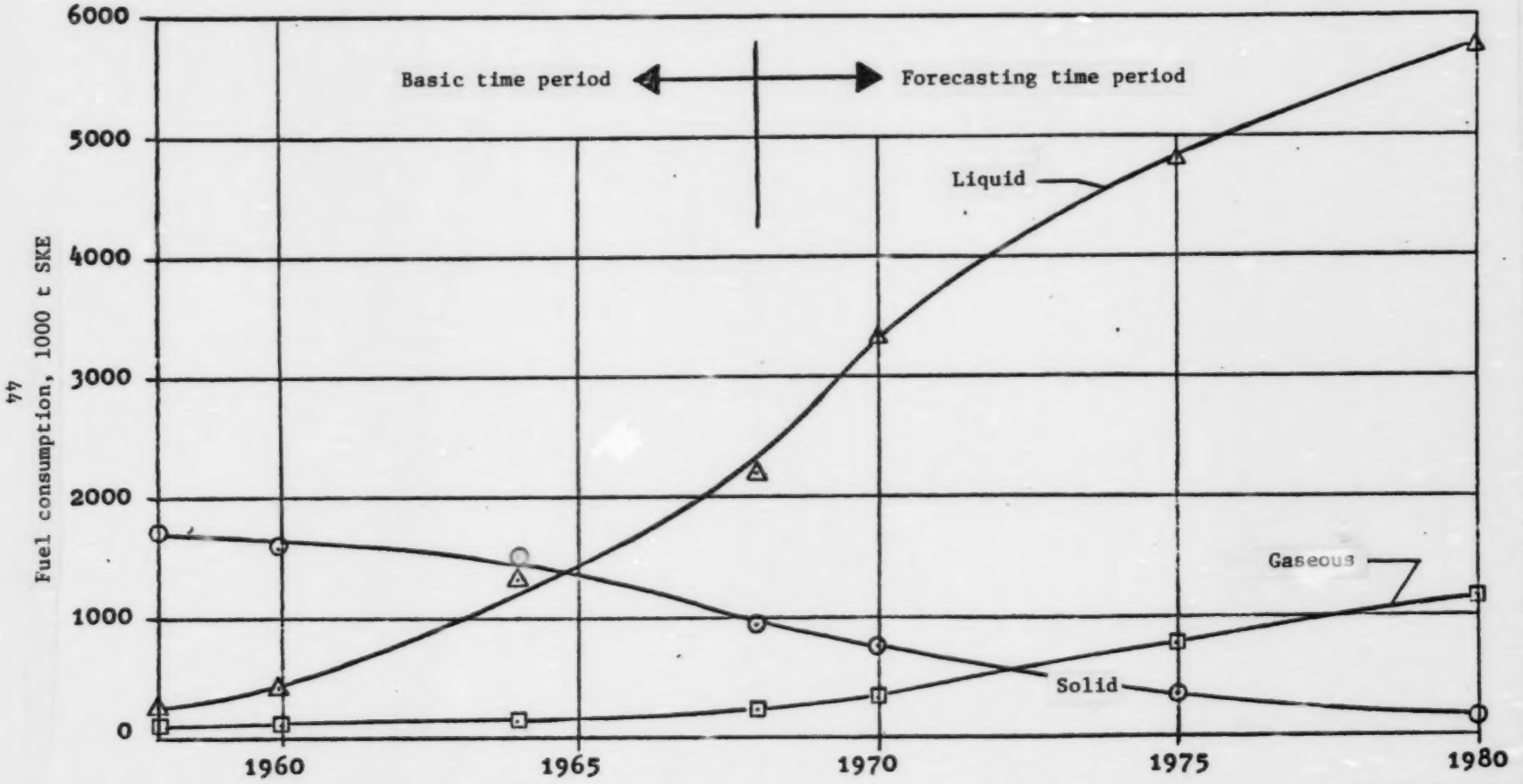


Figure 8. Projections of absolute fuel consumption values for the governmental district Oberbayern (according to DIW data).

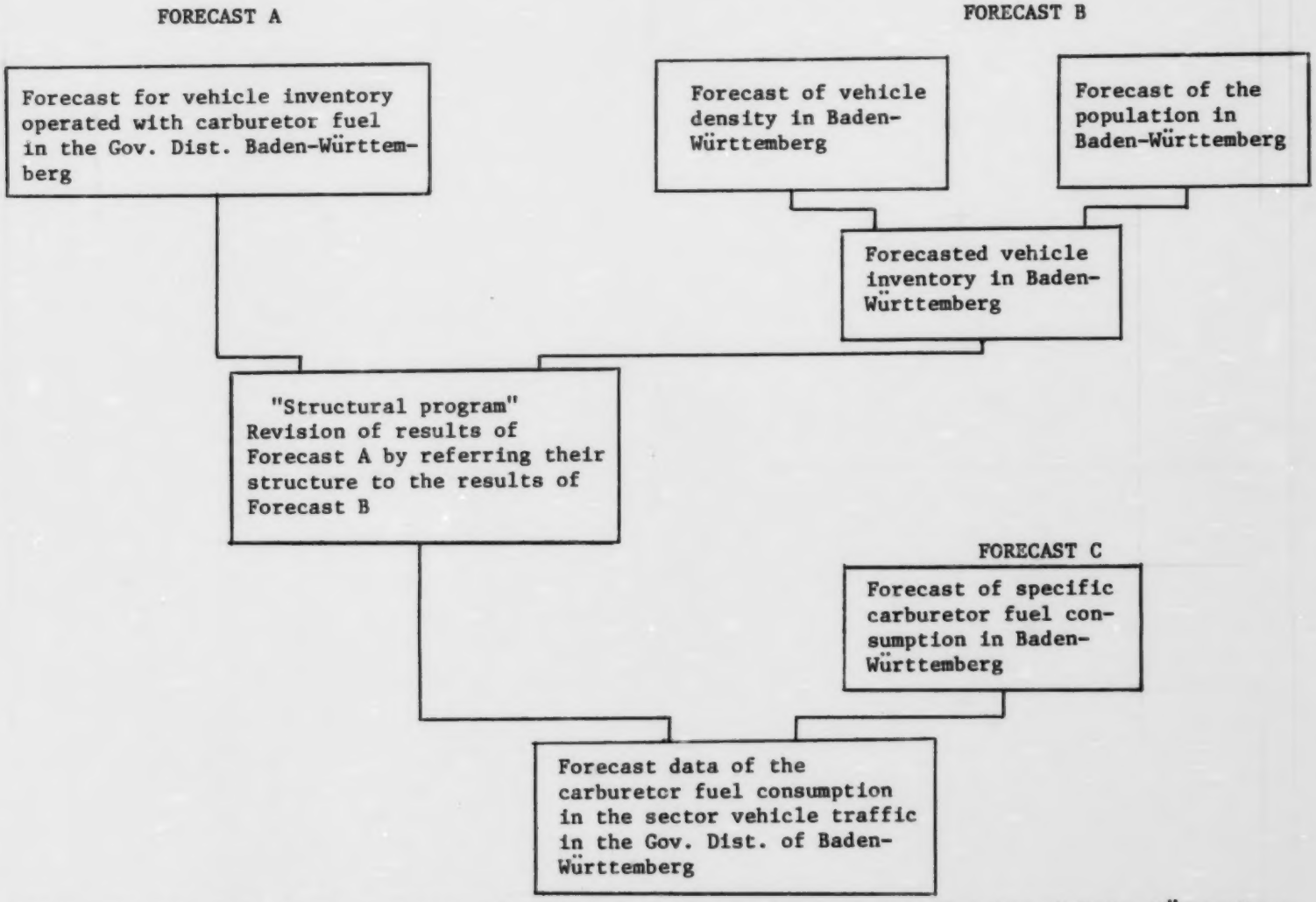

FORECAST A
FORECAST B
Forecast for vehicle inventory operated with carburetor fuel in the Gov. Dist. Baden-Württemberg
Forecast of vehicle density in Baden-Württemberg
Forecast of the population in Baden-Württemberg
Forecasted vehicle inventory in Baden-Württemberg
"Structural program" Revision of results of Forecast A by referring their structure to the results of Forecast B
FORECAST C
Forecast of specific carburetor fuel consumption in Baden-Württemberg
Forecast data of the carburetor fuel consumption in the sector vehicle traffic in the Gov. Dist. of Baden-Württemberg

Figure 9. Diagram for the carburetor fuel forecast for the Governmental District of Baden-Württemberg (according to DIW).

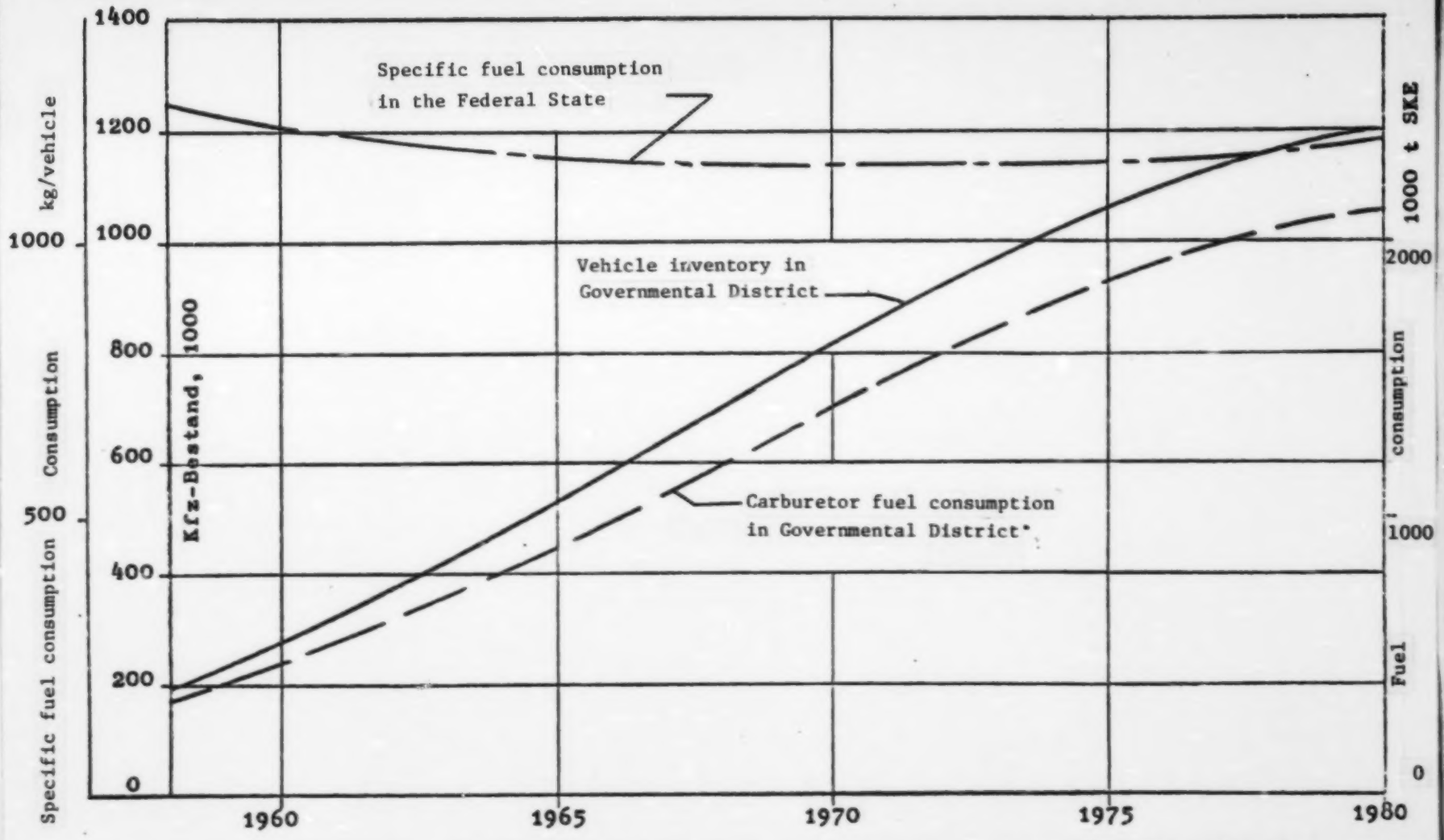


Figure 10. Forecast of carburetor fuels for the Governmental District Nordwürttemberg (according to DIW data).

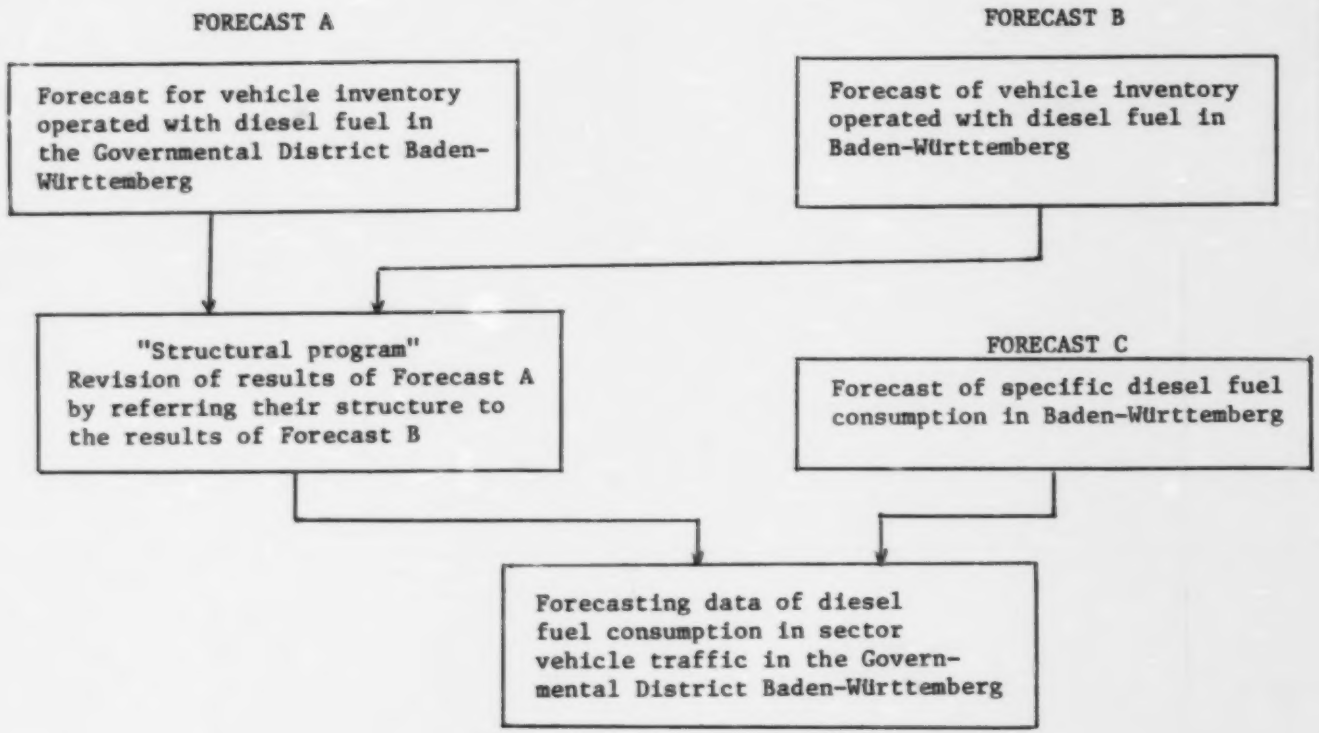
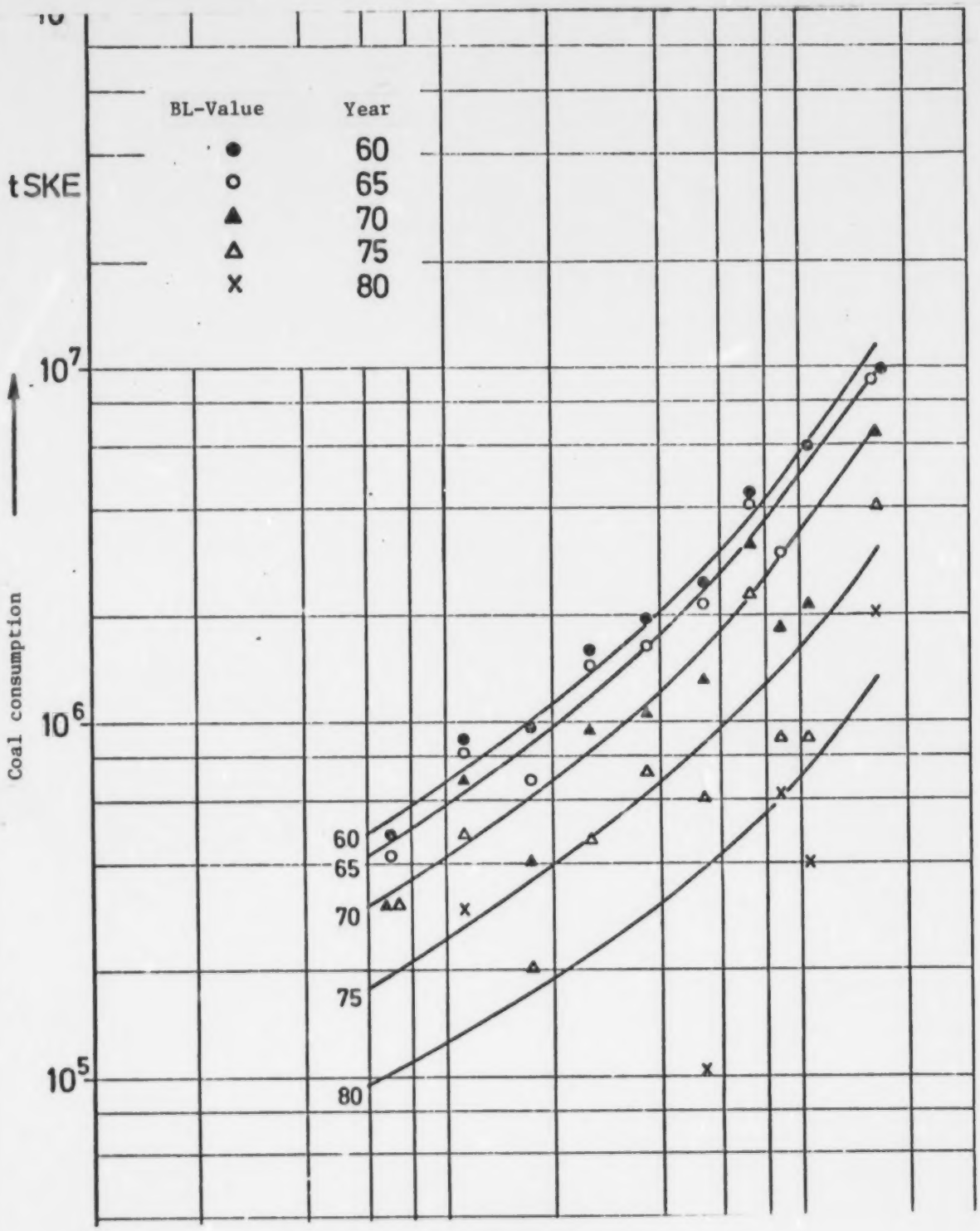

FORECAST A
Forecast for vehicle inventory operated with diesel fuel in the Governmental District Baden-Württemberg
FORECAST B
Forecast of vehicle inventory operated with diesel fuel in Baden-Württemberg
"Structural program"
Revision of results of Forecast A by referring their structure to the results of Forecast B
FORECAST C
Forecast of specific diesel fuel consumption in Baden-Württemberg
Forecasting data of diesel fuel consumption in sector vehicle traffic in the Governmental District Baden-Württemberg

Figure 11. Diagram for the diesel fuel forecast for the Governmental District Baden-Wurttemberg (according to DIW).


BL-Value
Year
60
65
70
75
80
tSKE
10^7
10^6
10^5
Coal consumption
60
65
70
75
80

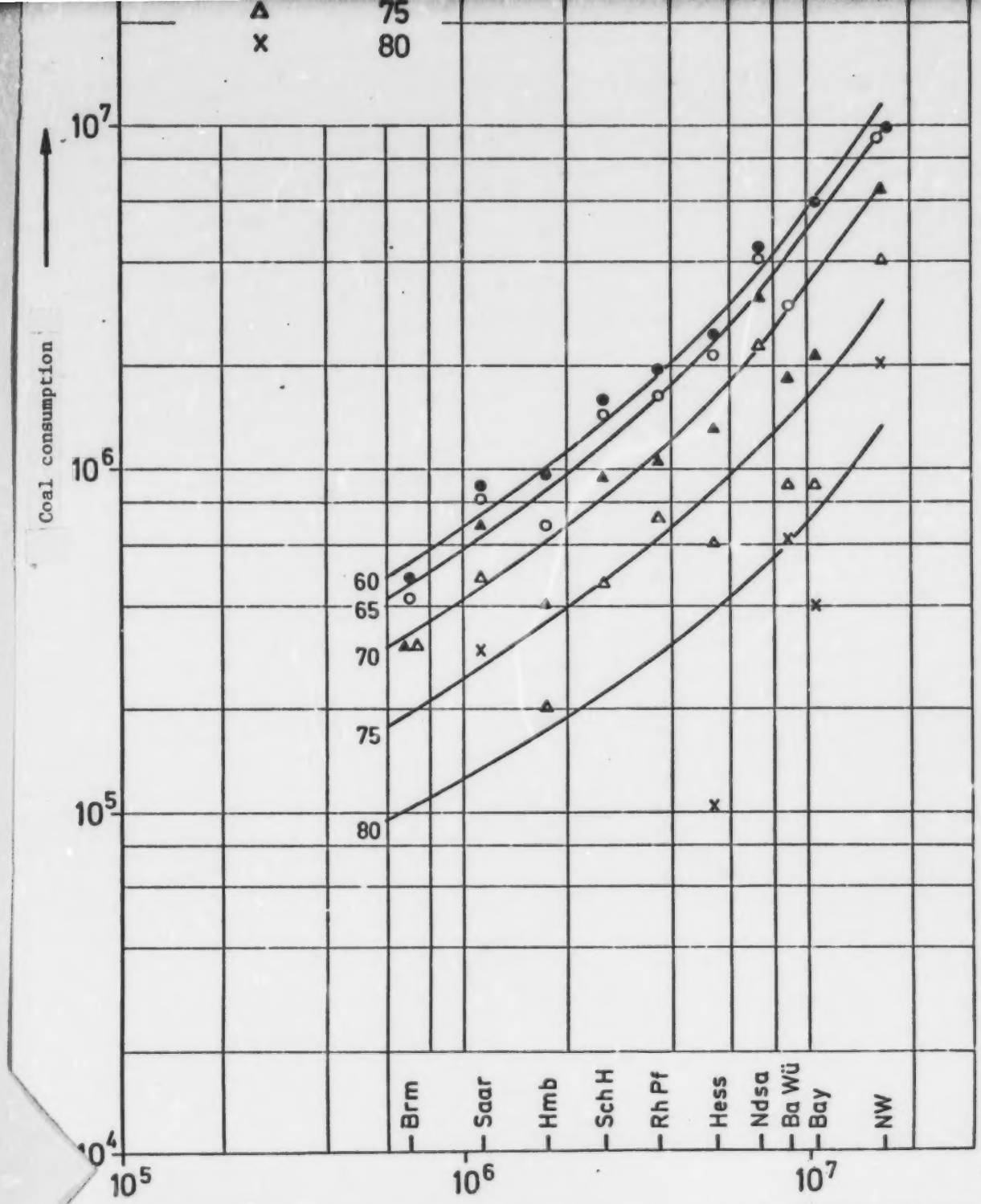


Figure 12. Coal consumption 1960 to 1980 in the states of the Federal Republic of Germany.

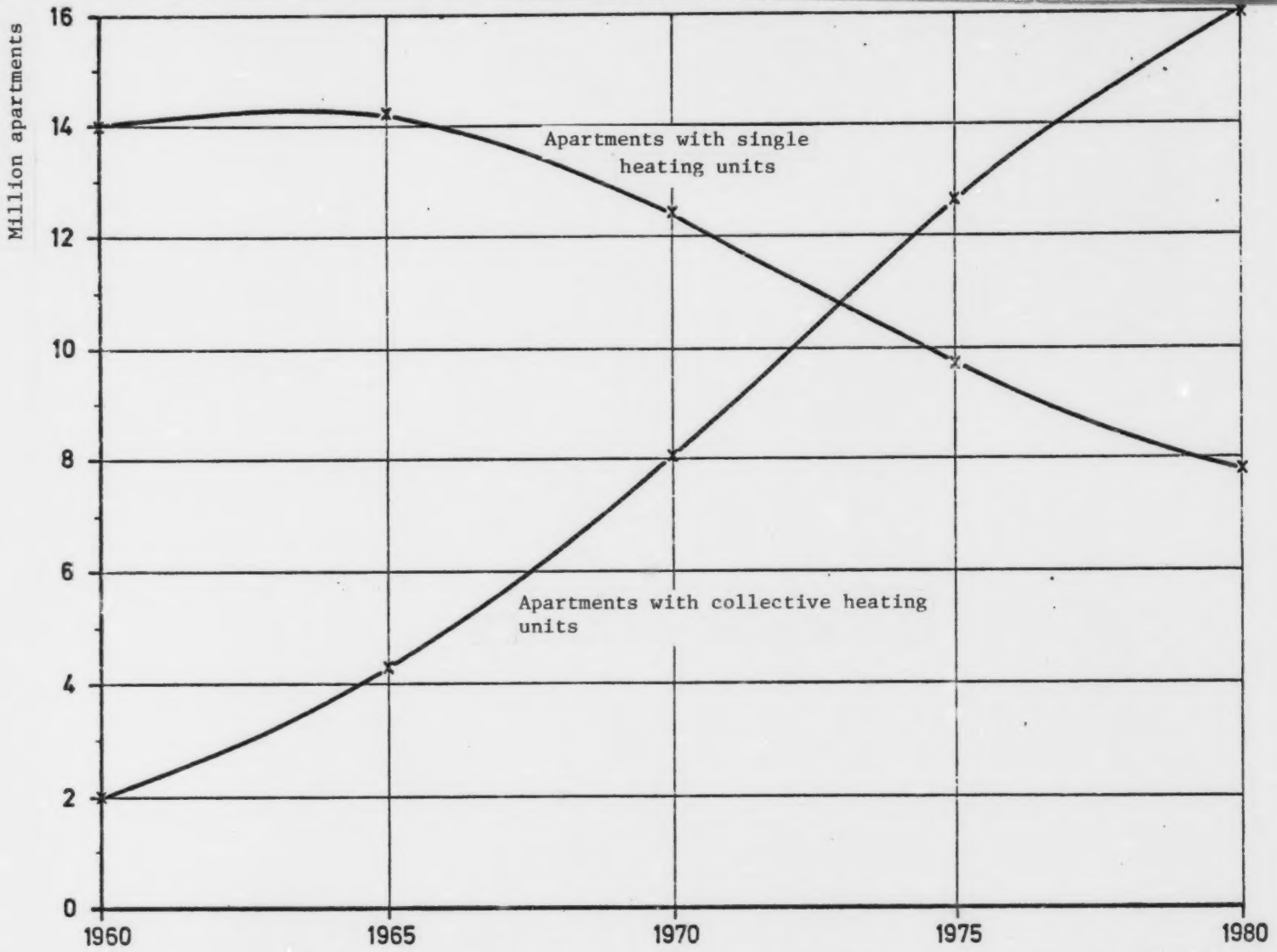


Figure 13. Forecast of the apartments with individual and collective heating units for the Federal Republic of Germany.

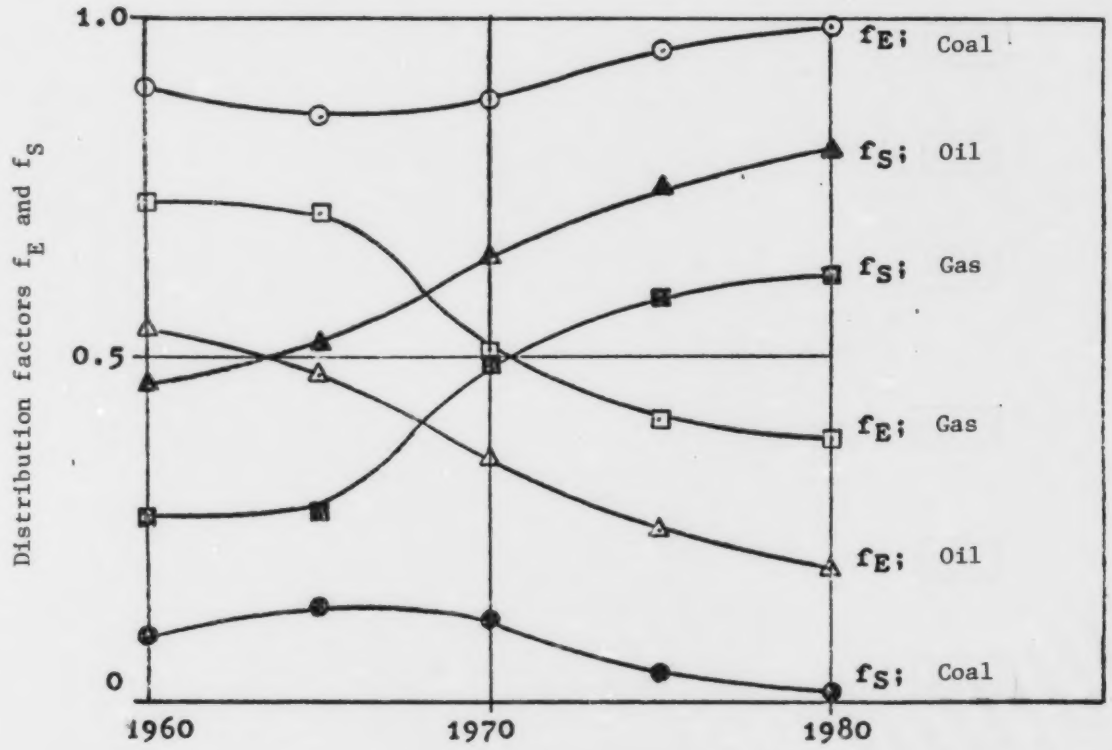


Figure 14. Projection of the distribution factor for individual and collective heating units.